EXHIBIT 1
DATE 2-25-13
HB 558

California Bearing Ratio (CBR)

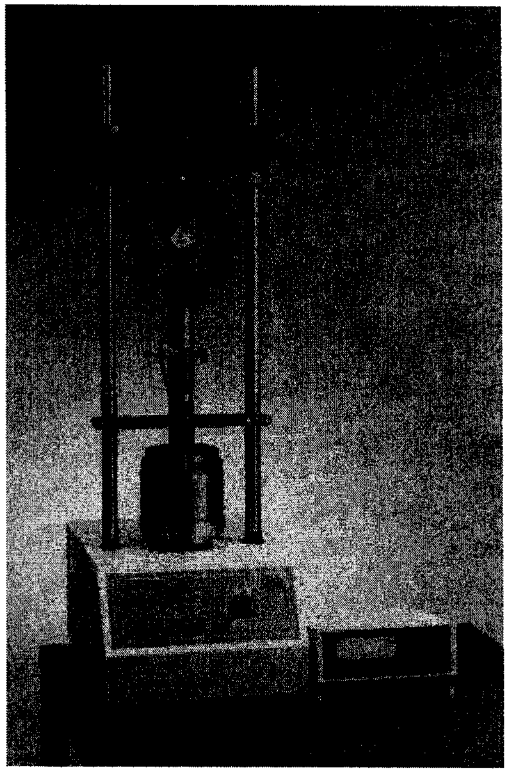
The California Bearing Ratio or CBR test (Table 5-27) is an indirect measure of soil strength based on resistance to penetration by a standardized piston moving at a standardized rate for a prescribed penetration distance (Figure 5-12). CBR values are commonly used for highway, airport, parking lot, and other pavement designs based on empirical local or agency specific methods (*i.e.*, FHWA, FAA, AASHTO). CBR has also been correlated empirically with resilient modulus and a variety of other engineering soil properties.

CBR is not a fundamental material property and thus is unsuitable for direct use in mechanistic and mechanistic-empirical design procedures. However, it is a relatively easy and inexpensive test to perform, it has a long history in pavement design, and it is reasonably well correlated with more fundamental properties like resilient modulus. Consequently, it continues to be used in practice.

Table 5-27. California Bearing Ratio (CBR).

Description	The California Bearing Ratio or CBR is an indirect measure of soil strength based on resistance to penetration.
Uses in Pavements	Direct input to some empirical pavement design methods Correlations with resilient modulus and other engineering properties
Laboratory Determination	AASTHO T 193 or ASTM D 1883. CBR is based on resistance to penetration by a standardized piston moving at a standardized rate for a prescribed penetration distance (Figure 5-12). CBR is defined as the ratio of the load required to cause a certain depth of penetration of a piston into a compacted specimen of soil at some water content and density, to the *standard load* required to obtain the same depth of penetration on a standard sample of crushed stone (usually limestone). Typically soaked conditions are used to simulate anticipated long term conditions in the field. The CBR test is run on three identically compacted samples. Each series of the CBR test is run for a given relative compaction and moisture content. The geotechnical engineer must specify the conditions (dry, at optimum moisture, after soaking, 95% relative compaction, etc.) under which each test should be performed.
Field Measurement	ASTM D 4429. Test procedure is similar to that for laboratory determination.
Commentary	Most CBR testing is laboratory based; thus, the results will be highly dependent on the representativeness of the samples tested. It is also important that the testing conditions be clearly stated: CBR values measured from as-compacted samples at optimum moisture and density conditions can be significantly greater than CBR values measured from similar samples after soaking, for example. For field measurement, care should be taken to make certain that the deflection dial is anchored well outside the loaded area. Field measurement is made at the field moisture content while laboratory testing is typically performed for soaked conditions, so soil-specific correlations between field and laboratory CBR values are often required.
Typical Values	See Table 5-28. For AASHO Road Test, CBR ≈ 100 for the granular base layer and about 30 for the granular subbase.

Figure 5-12. California Bearing Ratio test device (http://www.ele.com/geot/cali.htm).



USCS Soil Class	Field CBR
GW	60 - 80
GP	35 - 60
GM	40 - 80
GC	20 - 40
SW	20 - 40
SP	15 - 25
SM	20 - 40
SC	10 - 20
ML	5 - 15
CL	5 - 15
OL	4 - 8
MH	4 - 8
CH	3 - 5
OH	3 - 5

Unified Soil Classification System

The **Unified Soil Classification System** (USCS) is a soil classification system used in engineering and geology to describe the texture and grain size of a soil. The classification system can be applied to most unconsolidated materials, and is represented by a two-letter symbol. Each letter is described below (with the exception of **Pt**):

First and/or second letters

Symbol	**Definition**
G	gravel
S	sand
M	silt
C	clay
O	organic

Second letter

Letter	**Definition**
P	poorly graded (uniform particle sizes)
W	well-graded (diversified particle sizes)
H	high plasticity
L	low plasticity

If the soil has 5–12% by weight of fines passing a #200 sieve ($5\% < P_{\#200} < 12\%$), both grain size distribution and plasticity have a significant effect on the engineering properties of the soil, and dual notation may be used for the group symbol. For example, GW-GM corresponds to "well-graded gravel *with silt*."

If the soil has more than 15% by weight retained on a #4 sieve ($R_{\#4} > 15\%$), there is a significant amount of gravel, and the suffix "with gravel" may be added to the group name, but the group symbol does not change. For example, SP-SM could refer to "poorly graded SAND with silt" or "poorly graded SAND with silt and gravel."

[edit] Symbol chart

Major divisions			**Group symbol**	**Group name**
Coarse grained soils more than 50% retained on No.200 (0.075 mm) sieve	gravel > 50% of coarse fraction retained on No. 4 (4.75 mm) sieve	clean gravel <5% smaller than #200 Sieve	**GW**	well-graded gravel, fine to coarse gravel
			GP	poorly graded gravel
		gravel with >12% fines	**GM**	silty gravel
			GC	clayey gravel
	sand ≥ 50% of coarse fraction passes No.4 sieve	clean sand	**SW**	well-graded sand, fine to coarse sand
			SP	poorly graded sand
		sand with >12% fines	**SM**	silty sand
			SC	clayey sand

Fine grained soils more than 50% passes No.200 sieve	silt and clay liquid limit < 50	inorganic	**ML**	silt
			CL	clay
		organic	**OL**	organic silt, organic clay
	silt and clay liquid limit ≥ 50	inorganic	**MH**	silt of high plasticity, elastic silt
			CH	clay of high plasticity, fat clay
		organic	**OH**	organic clay, organic silt
Highly organic soils			**Pt**	peat

[edit] See also

- AASHTO Soil Classification System
- AASHTO
- ASTM International

[edit] References

Classification of Soils for Engineering Purposes: Annual Book of ASTM Standards, D 2487-83, **04.08**, American Society for Testing and Materials, 1985, pp. 395–408, http://www.astm.org/Standards/D2487.htm

Evett, Jack and Cheng Liu (2007), *Soils and Foundations* (7 ed.), Prentice Hall, pp. TBD

AASHTO T 193: Standard Method of Test for The California Bearing Ratio

Publication Date: Jan 1, 2010
SDO: AASHTO: American Association of State Highway and Transportation Officials

☐ DOD Adopted ☐ ANSI Approved Approved

This test method covers the determination of the California Bearing Ratio (CBR) of pavement subgrade, subbase, and base/course materials from laboratory compacted specimens. The test method is primarily intended for, but not limited to, evaluating the strength of cohesive materials having maximum particle sizes less than 19 mm (¾ in.).

When materials having maximum particle sizes greater than 19 mm (¾ in.) are to be tested, this test method provides for modifying the gradation of the material so that the material used for tests all passes the 19.0-mm (¾-in.) sieve while the total gravel 4.75-mm (No. 4) to 75-mm (3-in.) fraction remains the same. While traditionally this method of specimen preparation has been used to avoid the error inherent in testing materials containing large particles in the CBR test apparatus, the modified material may have significantly different strength properties than the original material. However, a large experience base has developed using this test method for materials for which the gradation has been modified and satisfactory design methods are in use based on the results of tests using this procedure.

Past practice has shown that CBR results for those materials having substantial percentages of particles retained on the 4.75-mm (No. 4) sieve are more variable than for finer materials. Consequently, more trials may be required for these materials to establish a reliable CBR.

This test method provides for the determination of the CBR of a material at optimum water content or a range of water content from a specified compaction test and a specified dry unit mass. The dry unit mass is usually given as a percentage of maximum dry unit mass from the compaction tests of T 99 or T 180.

The agency requesting the test shall specify the water content or range of water content and the dry unit mass for which the CBR is desired.

Unless specified otherwise by the requesting agency, or unless it has been shown to have no effect on test results for the material being tested, all specimens shall be soaked prior to penetration.

The values stated in SI units are to be regarded as the standard.

AASHTO T 180: Standard Method of Test for Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop

Publication Date: Jan 1, 2010
SDO: AASHTO: American Association of State Highway and Transportation Officials
☐ DOD Adopted ☐ ANSI Approved Approved

This method of test is intended for determining the relationship between the moisture content and density of soils when compacted in a given mold of a given size with a 4.54-kg (10-lb) rammer dropped from a height of 457 mm (18 in.). Four alternate procedures are provided as follows:

- *Method A*—A 101.60-mm (4-in.) mold: Soil material passing a 4.75-mm (No. 4) sieve Sections 4 and 5.

- *Method B*—A 152.40-mm (6-in.) mold: Soil material passing a 4.75-mm (No. 4) sieve Sections 6 and 7.

- *Method C*—A 101.60-mm (4-in.) mold: Soil material passing a 19.0-mm (¾-in.) sieve Sections 8 and 9.

- *Method D*—A 152.40-mm (6-in.) mold: Soil material passing a 19.0-mm (¾-in.) sieve Sections 10 and 11.

The method to be used should be indicated in the specifications for the material being tested. If no method is specified, the provisions of Method A shall govern.

This test method applies to soil mixtures that have 40 percent or less retained on the 4.75-mm (No. 4) sieve, when Method A or B is used and 30 percent or less retained on the 19.0-mm (¾-in.) sieve, when Method C or D is used. The material retained on these sieves shall be defined as oversize particles (coarse particles).

If the test specimen contains oversize particles and the test specimen used for field density compaction control, corrections must be made according to T 224 to compare the total field density with the compacted specimen. The person or agency specifying this method shall specify a minimum percentage of oversize particles below which correction for oversize need not be applied. If no minimum percentage is specified, correction shall be applied to samples with more than 5 percent by mass of oversize particles.

If the specified oversized maximum tolerances are exceeded, other methods of compaction control must be used.

Note 1—One method for the design and control of the compaction of such soils is to use a test fill to determine the required degree of compaction and a method to obtain that compaction. Then use a method specification to control the compaction by specifying the type and size of compaction equipment, the lift thickness, and the number of passes.

The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with ASTM E 29.

The values stated in SI units are to be regarded as the standard.